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ABSTRACT

A computer-displayed 3-D tic-tac-toe game was used to investigate adult perceptual biases in dealing with diagonal line orientations. Also investigated was the interaction between prior spatial ability and the effects of explicit visual modeling and structured practice on performance. Results indicated a strong selective difficulty in dealing with 3-dimensional diagonals. Spatial ability interacted with explicitness of instruction to produce differential effects that varied over trials. For high spatials, explicit modeling facilitated initial performance, while structured practice resulted in the most improvement over trials. These results are discussed in terms of instructional theory and implications for trait x treatment research. (Author)

DIAGONALITY IN ADULTS AND THE INTERACTION BETWEEN SPATIAL ABILITY AND EXPLICITNESS OF INSTRUCTION

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It is increasingly common for cognitive theorists to assume an intimate relationship among the processes of perceiving, knowing, and performing. The assumption that one learns about the world by means of actions performed upon it is central to many theories of knowledge acquisition. Piaget (1971) sees the process as one of internalizing actions and imitations into corresponding internal counterparts. Other theorists (e.g., Olson & Bruner, 1974) see actions as serving to confront the learner with the relevant choices in performing a task and thus provide the occasion for the pickup of information pertinent to those choices. As Olson (e.g., 1976) has pointed out, this information can be thought of as being of two kinds: information about the world (which Olson terms "knowledge") and information about the actions themselves ("skills"). While the same "knowledge" may be obtained from a wide variety of experiences, Olson suggests that "skills" may reflect the structure of the particular domain or medium through which learning takes place.

This notion of "skills" is conceptually attractive, but requires considerable elaboration to be useful as a psychological construct. It is a plausible hypothesis that "spatial ability" as measured by paper and pencil tests requiring the mental manipulation of spatial layouts and objects may reflect internal schematic operations of wide generality which may be considered as an example of "skills" in Olson's sense. Such a view finds considerable support from the literature on "mental rotations" (e.g., Metzler & Shepard, 1974), particularly given the similarity of the tasks employed in those experiments with items found on many tests purported to measure "spatiality". An understanding of the processes by which such cognitive skills are cultivated would be an important component of a theory of instruction.

Salomon (1974) has reported a series of experiments designed to test the hypothesis that specific schematic operations corresponding to spatial manipulations of objects can be acquired via exposure to analogous operations depicted in motion pictures. Salomon had eighth and ninth grade students view films or slides depicting such operations as "zooming-in" on details and the laying-out of solid objects. Subjects were also pre- and post-tested on relevant aptitudes to determine the effectiveness of the treatments. An additional hypothesis was that explicitness of presentation would interact with aptitude scores such that initially less skillful children would benefit most from the explicit modeling while those already possessing relevant aptitudes would benefit most from opportunities to "activate" these skills. This latter prediction follows from the argument that the presentation of ready-made schematic mediators might interfere with the performance of learners who already possess different but equally efficient mediators--and indeed, cases have been found in which the presentation of explicit mediators has resulted in interference (e.g., Bruner, 1961).

To test this latter hypothesis, Salomon presented the filmic operations at three levels of explicitness: <u>modeling</u>, <u>short circuit</u>, and <u>activation</u>. In the <u>modeling</u> condition, participants

viewed films depicting the gradual zooming-in on or laying-out of objects and were thus exposed to the fully explicit operations. In the short circuit condition, slides were presented showing only the initial and terminal states of the operation. Finally, in the activation condition, only the initial state was presented along with instructions to perform the operation.

Salomon's results strongly confirmed both hypotheses. The studies showed that at least two kinds of covert skills can be successfully modeled from film. Moreover, it was shown that learners with low relevant aptitudes benefited most from such modeling and that initially high performers are actually hindered. Thus, Salomon concludes that

> Educationally speaking, what our studies hint at is that certain mental skills may be adopted from communications media and thus be used to expand one's range of covert skills. The question, then, is not whether this is a "better" mode of instruction, but whether one can use visual media not just to acquire "knowledge that" but also "knowledge how to"; particularly for those learners who appear to have difficulty with other and more common types of instruction. (1974, p.511)

The present study was intended, in part, to extend Salomon's trait by treatment effect by manipulating explicitness of instruction in a somewhat more complex task situation. The task chosen for this purpose was a 3-dimensional tic-tac-toe game played on a 4x4x4 position cube-shaped "board" displayed as a computer-generated image on a CRT screen. This task was chosen for two reasons. First, it seemed likely that modelable perceptual-schematic operations of the type discussed above played an important role in the skilled performance of the task. Under the particular experimental conditions employed (described below), it was hoped that subjects' performance would largely reflect the ability to perform such operations.

The second reason for choosing the 3-D tic-tac-toe task was that an interesting analogy can be drawn between it and the tasks employed by Olson (1970) in his well-known studies of the acquisition of "diagonality" in children. In these studies, Olson demonstrated and attempted to account for the fact that young children, at an age at which they seem to have no trouble "understanding" the concept of a diagonal, nonetheless are often incapable of copying a diagonal pattern of checkers from one checkerboard to another even when the pattern being copied is always available for their inspection. This is true despite the fact that the same children have no difficulty performing the task with vertical or horizontal patterns.

The explanation for this phenomenon offered by Olson follows directly from the view that the acquisition of the skills relevant to performance in a given domain is a consequence of performatory attempts in that domain. It further follows that the perceptual skills one cultivates in a given performatory domain are biased by

the actions that one performs. In the case of an organism which locomotes and maintains orientation in the environment largely on the basis of visual information, Olson argues that it is reasonable to expect such invariant topological features as edgedness and proximity to exhibit perceptual primacy over features like slant, which do not maintain simple constancies under locomotion.

Applying these arguments to an analysis of the diagonality task, Olson postulates an ordering of difficulty, with verticals and horizontals being easier than diagonals. This is because dealing with the former involves the use of such perceptually primary topological features as edgedness, proximity of elements to each other, and parallelness to the reference axis defined by the checkerboard. Dealing with diagonals, however, requires the use of perceptually more complex "euclidean" cues such as "up and to the right," etc.

Returning now to the present experiment, it was reasoned that if Olson's analysis is correct, then the same ordering of difficulty as a function of line orientation should be manifest in the 3-D tic-tac-toe task. Specifically, vertical and horizontal configurations should be easiest, with diagonals more difficult. Furthermore, the 3-D task allows a further distinction between "plane diagonals" (i.e., those that lie on a plane parallel to one of the sides of the playing cube), and "3-D diagonals" (those which lie on no such plane). The latter orientations (of which there were four in the game cube) are, so to speak, "the most diagonal of all" in the sense of being least discriminable on the basis of topological cues, and should therefore be even more difficult than the plane diagonals.

Finally, it seemed plausible that, given a suitably unfamiliar performatory domain and an appropriate task, one should be able to demonstrate the diagonality effect even using normal adult subjects. This requirement for unfamiliarity accounts for our decision to employ the 3-D computer graphics display in the experiment

In summary, the hypotheses of the experiments were that (1) explicitness of instruction would interact with prior relevant spatial abilities such that initially lower-scoring subjects would benefit most from explicit visual modeling, and higher spatials from an opportunity for appropriately structured practice; and (2) task performance would reflect an ordering of difficulty based on orientation, with horizontal and vertical configurations being easiest, plane diagonals intermediate, and 3-D diagonals most difficult.

METHOD

Performance Task

The version of tic-tac-toe used as the experimental task was played on a cube-shaped "board" with each edge of the cube being four marker locations long. Thus, play took place within a 4x4x4

matrix of positions where "X's" or "O's" could be placed--yielding a total of 64 play positions. The rules of the game are basically similar to those of standard tic-tac-toe, i.e., the goal is to place four markers in a straight line in any direction while preventing the opponent from doing the same.

The playing cube was presented on a computer-driven C.R.T. screen as a 2-dimensional projection. Each of the 64 play-positions was represented as a small dot, any one of which could be selected by the player by means of a light pen. Since the 2-D image represented a parallel projection of the 3-D cube and no perspective or other such cues to depth were available, the image was completely ambiguous as to front and back and isomeric Necker cube-type reversals were possible. Nevertheless, the display produced a strong illusion of depth--an effect which was enhanced even further by the players' ability to rotate the image. This rotation was produced by a spring-loaded "joystick" which could be moved in two directions, controlling the rate of rotation of the image on the screen around both the vertical (Y) and horizontal (X) axes. Moving the joystick to the left or right produced a corresponding rotation around the Y axis and moving it foreward or backward caused a similar rotation around X. When the handle was in the neutral center position the image was motionless. The computer display was updated at a rate of 40 frames/sec thus producing a smooth, real-time display with no perceptible control lag. The image could be rotated 360 degrees around the Y axis, but in order to maintain a definite up/down direction in the image space, the X rotation was limited to plus or minus 27 degrees. Typical game displays are illustrated in Figure 1.

To obtain the performance measures, the computer served as the opponent, using a purely defensive strategy. Specifically, the algorithm first searched the board for a vector-of-three of its own markers (i.e., a win) and for vectors-of-three of the player's markers (a forced block), if these were not found, the search was continued for several key second-order patterns, such as the intersection of two vectors-of-two (indicating a forced win in two moves), etc. If none of these simple patterns was found, the move was selected on a random basis, thus insuring that the occurrence of each win-vector was equally likely.

Despite the random nature of the algorithm's offensive game, the defense is extremely effective and when playing against the typical opponent, the machine wins virtually every game. Thus, the measure of interest is not the number of games won, but rather, the number of moves until loss and the orientation in the image space of the computer win-vectors. It is argued that given the random nature of the computer's strategy, any systematic bias toward some orientation would be evidence for the relative difficulty in dealing with vectors-of-three in those orientations.

Apparatus

With the exception of the spatiality pretest, the entire experiment was presented and controlled by an ADAGE AGT-30

computer graphics terminal equipped with hardware character and vector generators, analog-to-digital converters, and a hybrid array which allows three-dimensional graphic images to be displayed in real time as 2-D projections on the 20 X 20 inch vector scan C.R.T. screen. Subjects interacted with the computer using the joystick and a bank of push-button switches used to make various responses.

Spatiality Measure

For use in testing the individual difference hypothesis, a measure of the participants' ability to imagine 3-dimensional spatial rotations was obtained using the Space Relations test (Form A) of the Differential Aptitude Test battery (Bennett, Seashore, and Wesman, 1947). The test is a paper and pencil instrument and involves the mental unfolding of abstract 3-dimensional objects. The standard time limit of 25 minutes was imposed and the score used was number right minus number wrong. Maximum possible score was 100.

Subjects

The subjects were 54 male undergraduate students at The Pennsylvania State University. All participants were enrolled in introductory psychology or educational psychology courses. While participation was voluntary, most received course credit for their participation. None had previous experience in similar experiments and all were naive as to the purposes of the experiment.

Only male subjects were used in order to avoid confounding spatial ability with other sex-linked differences which would be expected to correlate with that measure (Bock, 1973; Garron, 1970). In order to insure a nearly equal distribution of spatial ability scores in the three treatment conditions, the subjects were blocked into three levels of spatiality based on the space relations pretest. The cutoff scores for the high and low spatial groups were 68 and 56 points, respectively. Within the three levels, subjects were assigned randomly to treatment groups.

Procedure

Participation in the experiment consisted of two sessions separated by at least one day. In the first session, participants were administered the Space Relations test in accordance with the standardized instructions and procedures (Bennett, Seashore, and Wesman, 1947). Subjects were initially told only that the experiment concerned certain aspects of human problem solving and that they were about to be given a measure of their ability to visualize objects in space. The test was administered individually or in small groups.

The second session of the experiment was run on-line at the ADAGE terminal. The subject was seated at the computer console facing the C.R.T. with the joystick to his right and the bank of push-buttons to his left. He was told only to read the text presented on the screen--all further instructions were presented

on the screen and read silently by the subject. The experimenter was seated behind the subject and was available to answer questions throughout the session. A complete text of the entire experimental procedure may be obtained by writing the first author.

The first frame explained that the participant would soon challenge the computer in a "visual game" but that he must first familiarize himself with the controls. When he finished reading the frame he proceeded by pressing one of the buttons. Subjects in all conditions were then given two familiarization tasks. The first consisted of playing against the computer in three games of conventional (2-D) tic-tac-toe. This task was intended to give practice in the use of the light pen and the general procedures of the game. In the second familiarization task, subjects were presented with the cubical "board" on which they would play 3-D tic-tac-toe and were allowed to practice rotating it using the joystick; thus providing exposure to the ambiguities of the non-perspective, parallel projection of the cube.

In order to insure that any treatment effects were actually due to perceptual learning and not merely to verbal rule learning, the subject was then presented with a series of frames containing definitions of each possible line orientation followed by a rule for searching for each. To insure acquisition of this information, the presentation was followed by five frames which comprised a multiple choice test of comprehension of the rules just presented. Each frame presented a definition and the subject was required to indicate which line orientation it described. Response was made by pushing one of the push-buttons. If the subject did not receive a criterion score of four of the five questions correct, the instructional sequence was repeated up to three times, at which point the experimenter intervened to clarify the definitions. When criterion was reached, the program proceeded to one of the three experimental treatments.

<u>Modeling Group</u>. The subjects assigned to the modeling condition were presented with a frame telling them that they were to watch as various incomplete line orientations were pointed out and completed. They were reminded to attend to each of the four possible orientations. They were then presented with a series of 24 patterns representing game situations on the 3-D tic-tac-toe board. Each pattern contained a vector of three X's in one of the four orientations and several other randomly placed X's and O's. As the subject watched, the image was rotated to provide various views of the board. After the rotations, the three X's that comprised the incomplete win-vector were brightened successively in order to point out the vector. Finally, the missing X was inserted and blinked several times. The entire sequence took approximately 20 seconds and was repeated for each of the 24 patterns.

<u>Practice Group</u>. Subjects in the practice condition were presented with the same set of 24 game situations as the modeling

group; but instead of watching a preprogrammed sequence they were required to attempt to locate the win-vectors by pointing to the appropriate square with the light pen. The subject was free to control the position of the board using the joystick. Correct choices resulted in the X marker being placed and the message "RIGHT!!!" appearing at the top of the screen. An incorrect response was noted with an audible signal and the message "WRONG!!!". If the correct response was not made in approximately nine seconds, the marker was inserted and flashed several times and, after a brief pause, the next pattern was presented.

Control Group. The control condition was designed to provide a period of interaction with the computer without exposure to the tic-tac-toe game. It consisted of a "bouncing ball" game which involved aiming a ball at various targets using the joystick. Each control subject shot 32 balls which took roughly the same amount of time as the two experimental conditions (about nine minutes).

Performance Measure

Immediately after the treatment tasks, all subjects were given a performance measure consisting of eleven full games of 3-D tic-tac-toe with the computer as opponent. The player controlled board position with the joystick and indicated moves with the light pen. In the instruction frame preceding the first game, the player was told that the computer played very well and that he was not expected to win, but rather to play defensively and to "hold out as long as possible." These instructions were intended to minimize variability due to attempts at offensive strategies and focus subjects' attention on searching for and blocking the computer's vectors-of-three. When it was the player's turn to move, the message "YOUR MOVE..." appeared at the top left of the screen. After ten seconds, if no move had been made the message began to blink as a prompt to move immediately. After the subject selected his move using the light pen, there was a brief pause followed by the placement of the computer's marker.

At the start of each game, the image was positioned in a slightly rotated position which afforded a good view of the board. In each game, the subject made the first move. The game was terminated when either the player or the machine completed a vector-of-four. When this happened, a blinking line was drawn through the vector and after a pause of approximately five seconds, the board was cleared and the next game began. In the event that the player won a game, an extra game was played and the data from the won game was excluded from the analysis. Of the 597 games played, only three were lost by the computer. No subject won more than one game.

Two measures were obtained for each subject. The first consisted of a count of the number of subject moves until each game was lost. The second score obtained was designed as an "index of diagonality" and was meant to reflect the degree to which the orientations of computer win-vectors (i.e., subject

loss-vectors) were biased in favor of diagonals. Since the expected proportion of losses in each orientation given random moves is assumed to be a function of the number of possible win-vectors in that orientation, it is necessary that such an index adjust for those probabilities. Also, since the experimental hypotheses predict a disproportionately high number of 2-D and especially 3-D diagonal losses, it would also be desirable for the index to reflect those predictions in differential weightings. In order to meet these two critera, the following formula was used to produce the diagonality index:

$$Y(D) = -2\left[(p1 - P1) + (p2 - P2)\right] + (p3 - P3) + 3(p4 - P4)$$

where: Y(D) = Index of Diagonality
P1 = Expected proportion of vertical vectors
P2 = Expected proportion of horizontal vectors
P3 = Expected proportion of plane diagonals
P4 = Expected proportion of 3-D diagonals
p1-p4 = Obtained proportion of each orientation

Thus the index Y(D) represents a measure of "diagonality" with an expected value of zero to be used as a dependent measure in the study. A high value of this index reflects a tendency for players to lose games by overlooking diagonal vectors-of-three, after correcting for the chance probabilities. This measure allows both a test of the diagonality hypotheses and an assessment of any effects of the experimental treatments on the difficulty of the diagonals.

RESULTS

Orientation of Loss-Vectors

The obtained proportion of loss-vectors in each orientation averaged across all subjects were as follows: vertical--.11, horizontal--.07, plane diagonal--.31, 3-D diagonal--.50. In Figure 2 these proportions are compared with those which would be expected from random play. Fully half of the losses occurred on 3-D diagonal vectors, as compared with an expected proportion of .05, while far fewer losses than expected occurred in vertical and horizontal vectors. A chi-square test between observed and predicted proportions was highly significant ($\chi^2=2403$, $p < .001$). Thus, the hypothesis that players would find 3-D diagonals particularly difficult was strongly confirmed.

To determine the effects of the treatment conditions and of practice on the loss-vector orientations, the "index of diagonality" described in the previous section was computed for each subject. These data were then subjected to a 3x3x2 (treatments x spatial ability levels x blocks of trials) mixed analysis of variance with trials as a random factor. The first factor, treatments, was comprised of three levels: practice (P), modeling (M), and control (C); the second factor, spatial ability, had three levels: high spatials (HI), medium spatials (MED), and

low spatials (LO). The third factor, blocks of trials, had two levels: first five trials (1st) and second five trials (2nd). A table of means and standard deviations of each cell is presented in the appendix.

The analysis, summarized in Table 1, yielded no significant differences in the diagonality score across any of the three factors of the design and no significant interactions. These results suggest that whatever the nature of the difficulty in dealing with 3-D diagonals, it was apparently not affected by the experimental treatments, nor did players' skill in this respect appear to improve with practice. It also appears that the difficulty is shared more or less equally by players with different spatial ability scores. These results should, however, be interpreted with caution since given the relatively small number of subjects and games played as well as the relatively low intensity of the experimental treatments, the study probably lacks the power to justify confidence in negative results. This caution applies especially to the spatiality factor since the F test on this factor approached significance ($F(2,45) = 2.66$, $p < .08$).

Number of Moves

The average number of moves made by each player prior to loss was computed for the first and second half of the trials. These data were analyzed using a 3x3x2 mixed analysis of variance with all factors the same as in the diagonality score analysis.

The results of the analysis, presented in Table 2, indicate the presence of a triple interaction among treatments, spatial ability and trials, $F(4,45) = 2.80$, $p < .05$. The data were therefore resubmitted for separate two-factor analyses at each treatment and at each level of spatial ability in order to determine the specific loci of differences. Since there was no evidence for non-additivity in the data, the appropriate mean square values from the complete design were used as the error terms in each of the analyses.

Treatments

A summary of the 3x2 (levels of spatial ability x trials) analysis of variance for each treatment condition is presented in Table 3. Results at each level will be presented and discussed separately.

Modeling Group. The results of the analysis of the data of the modeling group show a significant interaction between spatial ability and blocks of trials. The cell means for each level of the interaction were analyzed by the Newman-Keuls test.

The results of this analysis, presented in Table 4, reveal that at this treatment level significant effects were limited to the high spatial subjects. This group showed an initial advantage over both middle and low spatials, but their performance was significantly lower in the second block of trials where the difference between groups disappears.

This result suggests that, contrary to the prediction made based upon Salomon's (1974) internalized mediators hypothesis,

high spatial subjects did benefit at least initially from explicit modeling, but that the effect weakened over trials, perhaps as the subjects began to revert to idiosyncratic strategies incompatible with those modeled.

<u>Practice Group</u>. Since the spatial ability x blocks interaction was not significant for the practice group (Table 3), Newman-Keuls analyses were performed on the simple main means. The results of these analyses, presented in Table 5, indicate only a superiority of medium and high spatials over the low spatial group. While an examination of the means (see the appendix) suggests an interaction in the opposite direction of that in the modeling group, this effect did not reach statistical significance.

<u>Control group</u>. The two-way analysis of variance on the control group data revealed no spatial ability x trials interaction so a Newman--Keuls follow up was performed on the simple main means. The results, presented in Table 5, shows that the medium spatials performed better than either the high or the low spatial groups. This finding was unexpected and an interpretation is not obvious.

<u>Levels of Spatial Ability</u>

To determine the presence of double interactions across treatments, separate two-way analyses of variance were performed at each level of spatial ability. A summary of these analyses is presented in Table 6. The two-way interaction was significant only for the high spatials, thus allowing Newman-Keuls tests to be performed on simple main means for the low and medium spatials. These tests showed no significant differences between treatments or trials at either the low or medium level of spatial ability. A table of these means and standard deviations is presented in the appendix.

Since the treatment X trials interaction was significant for the high spatial group, the Newman-Keuls procedure was applied to the cell means on these data. The results of this analysis are presented in Table 7. The means have also been plotted in Figure 3.

The analysis indicated that the interaction is primarily due to significant differences among the treatment groups in the initial block of trials, with the modeling group performing significantly better than both the practice and the control groups. This finding would seem directly contrary to the predictions made on the basis of the Salomon's (1974) study. However, an analysis of the graph of the modeling and practice means revealed a disordinal interaction across trials with the ordering of these two means reversed in the second block. There was both a significant improvement in the practice group's performance and a significant decline in the modeling group's scores (although the terminal differences between groups did not reach significance). This result--together with the previously described interactions between trials and spatial ability in the modeling condition--suggest at least tentatively that the

treatment conditions interacted with spatial ability in determining how the players were able to benefit from the experience of actually playing the game. Thus, if one considers the various treatment effects in terms of subjects' ability to benefit from practice (rather than initial performance), the results are generally supportive of Salomon's findings.

DISCUSSION

The results of the present study are of interest on at least three levels. First, the demonstration of diagonality in adults supports the reasoning behind Olson's (1970) proposed ordering of difficulty in dealing with various line orientations and confirms the tic-tac-toe task as an interesting and potentially useful experimental task. Second, the results of the experimental manipulation, while not clear cut, provide at least tentative support to Salomon's (1974) finding that strategies for dealing with measured prior spatial manipulations can be internalized through visual modeling, and that the explicitness of the modeled display interacts with spatial ability. Finally, the patterns of interaction found in the data are of considerable methodological interest to the researcher engaged in the study of phenomena involving trait-by-treatment interactions. Each of these issues will be discussed in turn.

Diagonality and the Adult Performer

The pronounced difficulty that the adult subjects in the present study had in detecting and blocking loss-vectors which were oriented as 3-D diagonals strikingly resembles the difficulty encountered by Olson's (1970) four-year-olds in the analogous 2-D task. If one assumes that college undergraduates should have no difficulty in conceptualizing a 3-D diagonal (an assumption which was corroborated by each subject's successful performance in the pretest involving the definition of each line orientation), then this result strongly supports the contention that the difficulty is perceptual, not conceptual in nature; i.e., the source of the subjects' difficulties with the diagonals was not a lack of adequate conceptualization of what to look for, but rather some difficulty in executing the appropriate visual search which would lead to the apprehension of the critical information to specify the impending loss and thus to allow the appropriate blocking move.

Whatever the specific nature of this difficulty, it was not remedied merely by increasing familiarity with the task or with the kinds of instruction attempted in this study. While both practice and the instructional treatments significantly altered scores based on the number of moves until loss, both factors showed a striking lack of effect on the diagonality scores, with means across these factors being virtually equal. In fact, the only factor related to the effects of diagonality on performance was spatial ability, and even here, the differences failed to

reach statistical significance.

Interaction Between Spatial Ability and Explicitness of Instruction

The complexity of the obtained interactions in the game length data and the post-hoc nature of the interpretation of them necessarily equivocates conclusions drawn concerning the hypothesized spatiality by explicitness interaction. If, however, one tentatively accepts the interpretation (further elaborated in the next section) that the anomalous pattern of results in the early trials was a product of the rather extreme unfamiliarity of the subjects with both the computer graphics medium and with the experimental task, then the results may cautiously be considered as a partial replication and extension of Salomon's (1974) demonstration of the internalization of schematic codes or strategies via modeling from a visual display.

In the present study, as in Salomon's, it was found that, at least in the latter trials, subjects with an initially high level of a relevant ability (i.e., spatiality) were able to benefit from a non-specific "activation" display, whereas they experienced interference in the more specific modeling of a particular strategy. The effect is less clear for the other two levels of spatial ability, both because of an apparent floor effect for the low spatials and of partially conflicting significance tests on simple effects--probably due to lack of power. It is, however, at least reasonably clear that the medium spatials benefited more from the explicit modeling than from the unstructured practice.

It should be noted that the greater complexity of the present task, compared with that used by Salomon, allows a correspondingly greater confidence in the applicability of the results to real-world educational questions. The price that is paid is that it is somewhat less clear exactly what was internalized from the instructional displays. While further research is clearly indicated here, a careful analysis of the present study can be of some help in this regard. The most obvious possibility is that the subjects merely learned more about the 3-D tic-tac-toe game. While some amount of this kind of learning must surely have taken place, this alone is clearly inadequate to account for the data since it does not explain the marked decrement in performance across trials experienced by the high spatials under the explicit modeling condition. Much the same case could be made against the possibility that it was a straightforward gain in familiarity with the computer graphics medium which elicited the improvement. This is supported by the fact that in post-experimental interviews very few of the subjects reported any familiarity with computer displays of the kind used in the study and, in particular, there is no evidence that subjects in the three spatiality levels differed in this respect.

Whatever the nature of the internalized information it is fairly clear from the differential nature of the effects that, to use Olson's (1972) terms, it was more like a 'skill' or strategy than 'knowledge'; i.e., it is not likely that the performance

differences reflected variations in how much the subjects "knew" about 3-D tic-tac-toe in the sense of explicit, verbalizable facts or characteristics of the game. Nor is it the case that what was learned in the modeling condition was information that combined additively to improve performance, since it had opposite effects with medium and high spatials. Rather, it seems more likely that what was internalized from the display represented covert, schematic operations that were useful in performing the task in the rather unfamiliar computer graphics medium. The precise nature of these operations remains unclear, but two obvious candidates are (1) a systematic scanning of the various potential loss-vector orientations on the board; and (2) a "perspective shifting" operation in which the board was considered from several orientations, perhaps by means of a "mental rotation" type of operation. Both of these operations were explicitly modeled in the modeling display.

Moreover, if these operations are considered as optional means to a common end (i.e., as strategies), rather than as essential components of a skilled performance, then the interference effects observed with the high spatials seems less anomalous. These subjects might be expected to bring with them to the task some fairly well-developed strategies for dealing with similar situations (indeed, this may be what it <u>means</u> to be "high spatial" in the present context). If the particular strategies presented in the instruction were significantly different from these idiosyncratically developed but perhaps equally efficient approaches to the task, then interference could be expected. The performance decrement over trials might reflect an initial, successful application of the modeled strategies, followed by a partial reversion to the subject's preferred (and conflicting) strategies. With further practice, this conflict would no doubt have been resolved, thus reversing the interference effect.

We might also consider these results with respect to the development of a theory of instruction. To the extent that such a theory would be expected to prescribe the optimal instructional means for a given learner at a given level of progress, the present study is of significance. It suggests that in tailoring instruction to the individual learner, the crucial factor may not be individual differences in overall level of achievement (i.e., mastery of content material), but rather, the particular range of mental skills that the learner has acquired in relation to the requirements of a given class of performance. As Olson (e.g., 1976) has argued forcefully, it may be that the range of such mental skills that are developed in the course of formal schooling may be of greater ultimate consequence than the particular content that is taught. It is in these matters that the study of individual differences may prove to have the greatest ultimate impact on instructional practice.

The Role of Practice Effects in Trait-by-Treatment Research

Perhaps the most clearly interpretable and immediately significant result of the present study does not relate directly to the initial experimental hypotheses. The particular pattern of interactions obtained in the data are of unique interest to the researcher engaged in research involving trait-by-treatment interactions.

Despite an initial enthusiasm and continued high level of interest in research problems involving the predictions of trait-by-treatment interactions since Cronbach's (1957) influential paper, the net yield of the enterprise in terms of interesting and useful data has been disappointing (see Cronbach & Snow, 1975). Various reasons have been put forth for this lack of success. Cronbach and Snow (1975) attribute it primarily to naive experimental designs, small sample sizes, and inappropriate statistical procedures. DiVesta (1973, 1975) has implicated an inadequate consideration of intervening cognitive processes employed by learners and a lack of sufficiently rigorous theoretical bases for experimental work. The outcome of the present study suggests yet another pitfall which may be encountered in such research. The pattern of means across trials strongly suggest that practice effects had a profound influence on the ways in which the experimental treatments interacted with spatial ability.

More specifically, the interactions found in the early trials were very nearly the reverse of those predicted on theoretical grounds. The high spatials, in particular, performed best in the modeling condition--the one in which they had been expected to experience interference. On the second block, however, this pattern was reversed and their performance level actually decreased with the additional practice. Apparently, the novelty of the task and/or the performatory medium had the effect of increasing the spatiality demands of the task and thus effectively putting our high spatial subjects in the position that lower spatials would otherwise have faced, and producing an extreme floor effect for the other groups. Once the subjects had acclimated themselves to the experimental task, these effects disappeared and something closer to the expected results was obtained.

Newell (1973) has made a case that, given the current state of theory in cognitive psychology, the prevailing practice of administering a large number of practice trials for which the data are never analyzed or often even recorded is ill-advised. It is often the case that the adoption of a single strategy and the achievement of a stable level of performance on a task is a process that takes a considerable amount of time--and may often be of at least as much interest as the final state itself. In the present case, a large number of practice trials would have obscured an interesting aspect of the data. Even worse, if the data had been collapsed across trials, the interactions would have cancelled, giving the appearance of no treatment effects at all. It is suggested that similar effects are a potential source of

problems in many trait-by-treatment designs and should be guarded against by designing experiments such that practice and other task-acclimation effects can be explicitly examined.

REFERENCES

Bennett, G. K., Seashore, H. G., & Wesman, A. G. Space relations test (Form A). The differential aptitude tests. New York: The Psychological Corporation, 1947.

Bock, R. D. & Kolakowski, D. Further evidence of sex-linked major gene influences on human spatial visualizing ability. American Journal of Human Genetics, 1973, 25, 1-14.

Bruner, J. S. The act of discovery. Harvard Education Review, 1961, 31, 40-52.

Cronbach, L. J. The two disciplines of scientific psychology. American Psychologist, 1957, 12, 671-684.

Cronbach, L. J. & Snow, R. E. Aptitudes and instructional methods: A handbook for research on interactions. New York: Irvington Publishers, 1975.

Di Vesta, F. J. Theory and measures of individual differences in studies of trait by treatment interactions. Educational Psychologist, 1973, 10, 67-75.

Di Vesta, F. J. Trait-treatment interactions, cognitive processes, and research on communication media. AV Communication Review, 1975, 23, 185-196.

Garron, D. C. Sex-linked, recessive inheritance of spatial and numerical abilties, and Turner's syndrome. Psychological Review, 1970, 77, 147-252.

Metzler, J. & Shepard, R. Transformational studies of the internal representation of three-dimensional objects. In R. L. Solso (Ed.), Theories in cognitive psychology: The Loyola symposium. New York: Wiley, 1974.

Newell, A. You can't play twenty questions with nature and win: Projective comments of the papers in this symposium. In W. Chase (Ed.), Visual information processing. New York: Academic Press, 1973.

Olson, D. R. Cognitive development: The child's acquisition of diagonality. New York: Academic Press, 1970.

Olson, D. R. On a theory of instruction: Why different forms of instruction result in similar knowledge. Interchange, 1972, 3, 9-24.

Olson, D. R. Toward a theory of instruction. Educational Psychologist, 1976, 12, 14-35.

Olson, D. R., & Bruner, J. S. Learning through experience and learning through media. In D. R. Olson (Ed.), _Media and symbols: The forms of expression, communication and education_. Seventy-third yearbook of the National Society for Studies in Education (Part 1). Chicago: University of Chicago Press, 1974.

Piaget, J. _Biology and knowledge_. Chicago: University of Chicago Press, 1971.

Salomon, G. Internalization of filmic schematic operations in interaction with learners' aptitudes. _Journal of Educational Psychology_, 1974, _66_, 499-511.

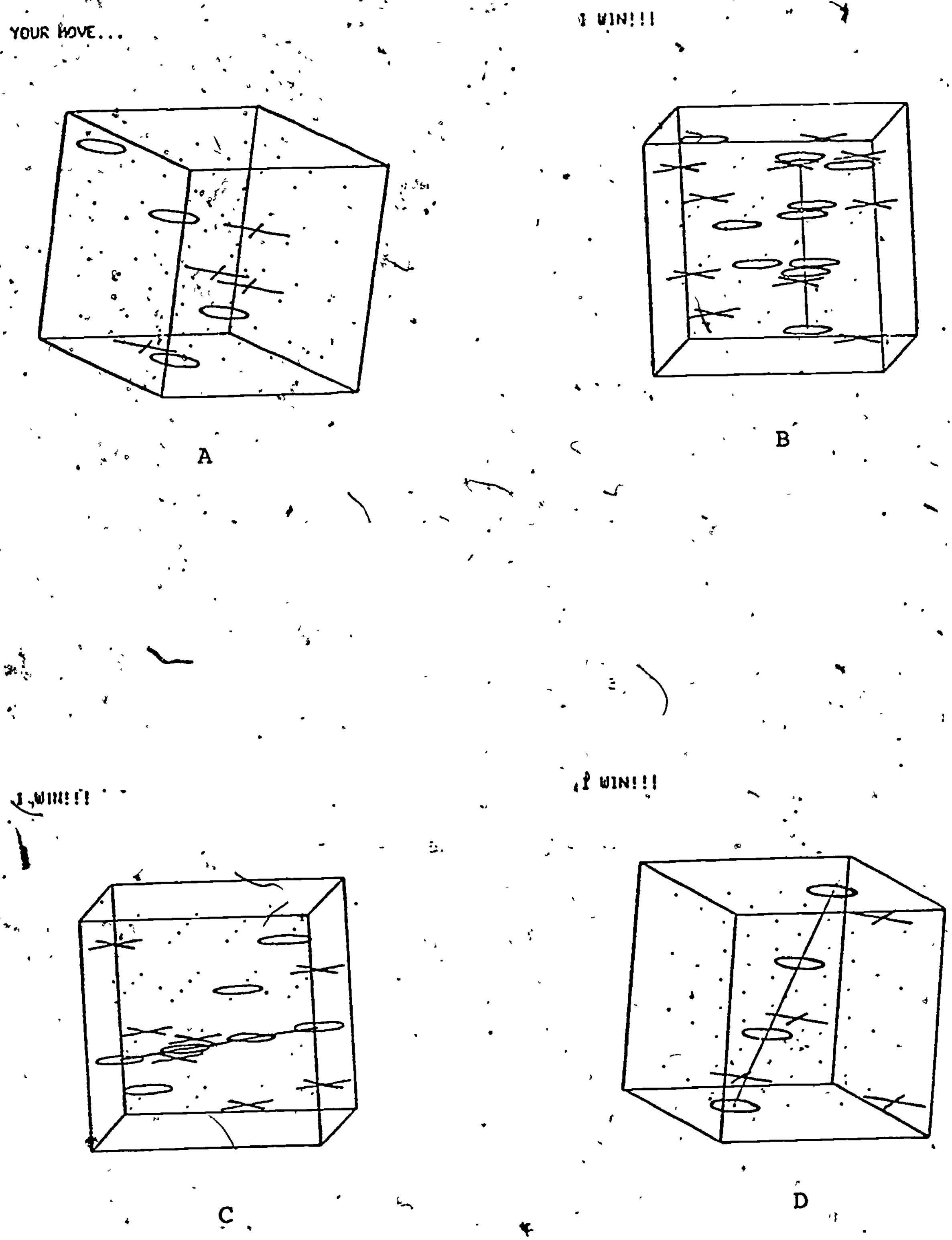

Figure 1. Typical game displays: After four rounds (A), vertical loss-vector (B), plane diagonal loss-vector (C), 3-D diagonal loss-vector (D).

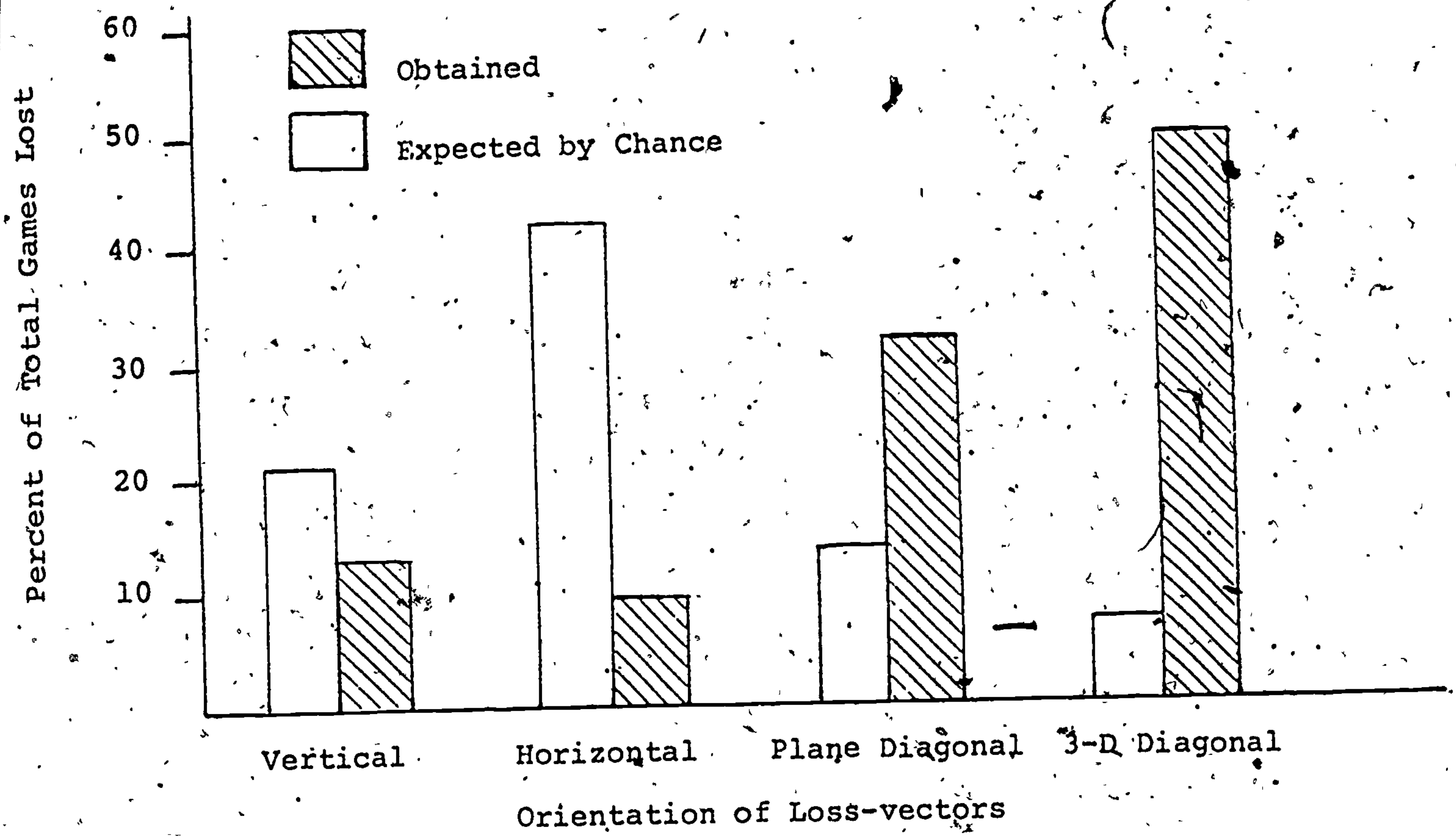

Figure 2. Percentage of loss-vectors in each orientation: Expected by chance and obtained.

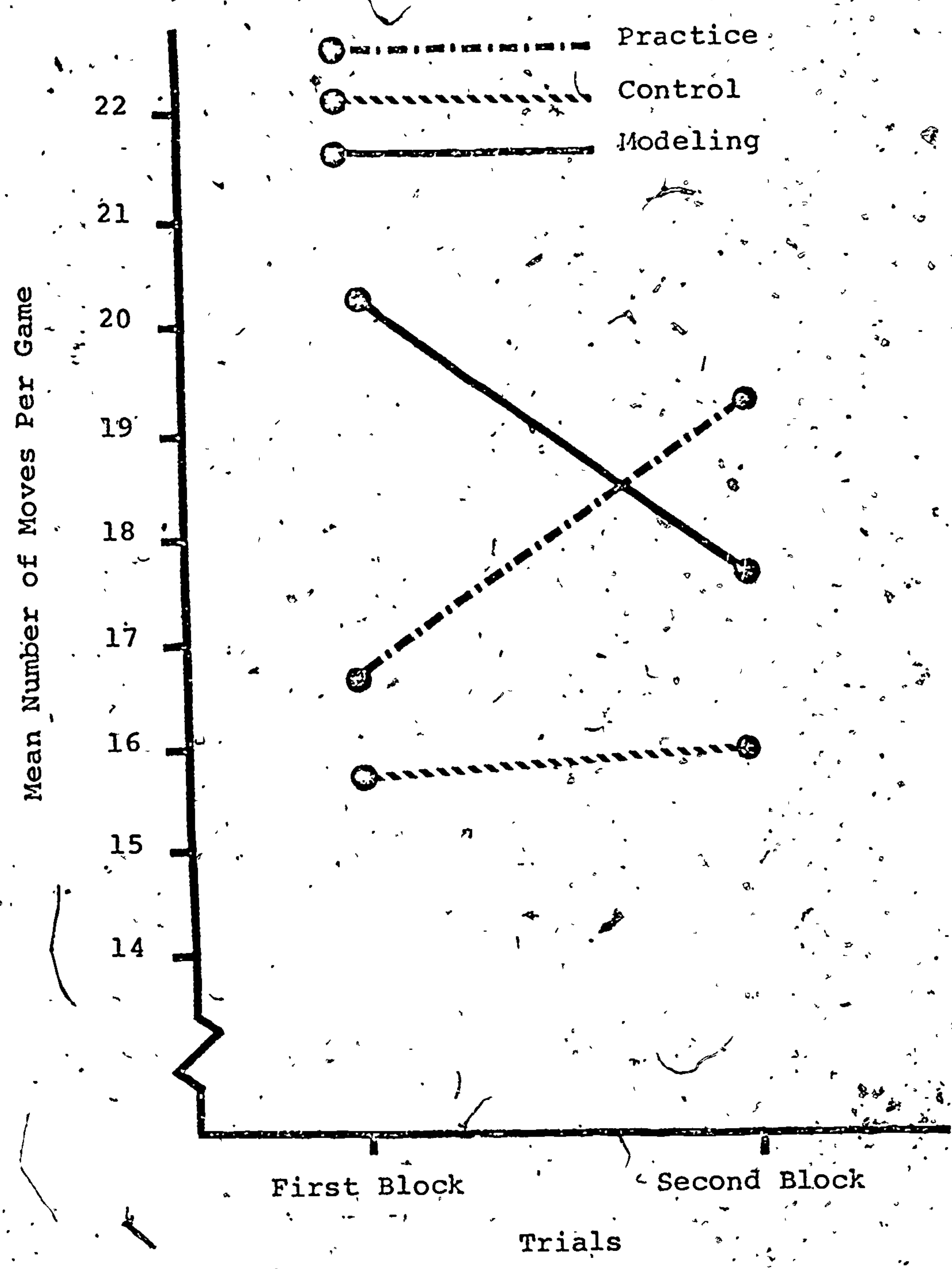

Figure 3. Mean number of moves of high spatial subjects under three treatment conditions and two block trials.

TABLE 1

Summary Table for Analysis of Variance of Diagonality Scores for Total Design

Source	df	MS	F	Prob.
Between Subjects				
Treatments (T)	2	.26	.34	
Spatial Ability (SA)	2	2.03	2.66	.081
T x SA	4	.38	.50	-
Error Between	45	.76		
Within Subjects				
Trials (TR)	1	.85	.84	
T x TR	2	.04	.04	
SA x TR	2	.02	.02	
T x SA x TR	4	.95	.95	
Error Within	45	1.01		

TABLE 2

Summary Table for Analysis of Variance of Number of Moves for Total Design

Source	df	MS	F	Prob.
Between Subjects				
Treatments (T)	2	6.58	.62	
Spatial Ability (SA)	2	33.92	3.22	.049
T x SA	4	18.89	1.79	.147
Error Between	45	10.54		
Within Subjects				
Trials (TR)	1	16.02	3.65	.063
T x TR	2	3.91	.89	
SA x TR	2	4.76	1.08	.347
T x SA x TR	4	12.32	2.80	.037
Error Within	45	4.39		

TABLE 3

Summary Table for Analysis of Variance of Number of Moves for Three Levels of Spatial Ability and Two Blocks of Trials, at Three Levels of Treatment

Source	Modeling df	Modeling MS	Modeling F	Modeling Prob.	Practice df	Practice MS	Practice F	Practice Prob.	Control df	Control MS	Control F	Control Prob.
Between Subjects												
Spatial Ability (SA)	2	16.03	1.52	.230	2	17.23	1.63	.207	2	38.44	3.64	.034
Error Between	45	10.54										
Within Subjects												
Trials (TR)	1	.004	.001		1	9.40	2.14	.150	1	14.44	3.29	.076
SA x TR	2	19.26	4.39	.018	2	5.79	1.31	.280	2	4.36	.99	
Error Within	45	4.39			45	4.39			45	4.39		

Note: Error terms are those of the complete design.

TABLE 4

Multiple Comparison of Mean Number of Moves of Subjects in Modeling Condition at Three Levels of Spatial Ability and Two Blocks of Trials

Trials	Low Spatials Mean	Low Spatials N-K*	Medium Spatials Mean	Medium Spatials N-K*	High Spatials Mean	High Spatials N-K*
First Half	16.20		16.40		20.40	
N-K*						
Second Half	17.26		18.27		17.54	
N-K*						

*Brackets indicate non-significant differences between means at the .05 level as determined by the Newman-Keuls Test.

TABLE 5

Multiple Comparison of Mean Number of Moves of Subjects in Practice and Control Conditions: Simple Main Effects of Spatial Ability and Blocks of Trials

Practice Group					
Spatial Ability			Trials		
Condition	Mean	N-K*	Block	Mean	N-K*
Low	15.57		First	16.40	
Medium	17.30		Second	17.42	
High	17.83				

Control Group					
Spatial Ability			Trials		
Condition	Mean	N-K*	Block	Mean	N-K*
Low	15.93		First	16.33	
High	15.93		Second	17.60	
Medium	19.03				

*Brackets indicate non-significant differences among means at the .05 level as determined by the Newman-Keuls Test.

TABLE 6

Summary Table for Analysis of Variance of Number of Moves for Three Treatment Groups and Two Blocks of Trials, at Three Levels of Spatial Ability

Source	Low Spatials				Medium Spatials				High Spatials			
	df	MS	F	Prob.	df	MS	F	Prob.	df	MS	F	Prob.
Between Subjects												
Treatments (T)	2	4.27	.40		2	11.79	1.19	.314	2	28.30	2.69	.079
Error Between	45	10.54			45	10.54			45	10.54		
Within Subjects												
Trials (TR)	1	4.56	1.04	.313	1	13.94	3.18	.081	1	.04	.01	
T x TR	2	5.61	1.28	.288	2	.99	.26		2	21.96	5.00	.011
Error Within	45	4.39			45	4.39			45	4.39		

Note: Error terms are those of the complete design.

TABLE 7

Multiple Comparison of Mean Number of Moves of High Spatial Subjects Under Three Treatment Conditions and Two Blocks of Trials

Trials	Control Mean	Control N-K*	Practice Mean	Practice N-K*	Modeling Mean	Modeling N-K*
First Half	15.87		16.60		20.40	
N-K*						
Second Half	16.00		19.14		17.54	
N-K*						

*Brackets indicate non-significant differences among means at the .05 level as determined by the Newman-Keuls Test.

APPENDIX

TABLES OF MEANS AND STANDARD DEVIATIONS

TABLE 8

Means and Standard Deviations:
'Diagonality' Measure--Pooled Across Trials

Condition	Spatiality Scores						Pooled Across Spatiality Scores	
	High n=6		Medium n=6		Low n=6		n=18	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Control	2.07	.73	2.36	1.00	2.59	1.26	2.34	1.04
Modeling	1.97	.99	2.52	.85	2.11	1.77	2.20	1.29
Practice	1.86	.99	2.29	1.91	2.41	1.07	2.18	1.41
Pooled Across Treatments	1.97	.92	2.39	1.34	2.37	1.41		

TABLE 9

Means and Standard Deviations:
Number of Moves in Modeling Condition

Block of Trials	Spatiality Scores: High n=6 Mean	SD	Medium n=6 Mean	SD	Low n=6 Mean	SD	Pooled Across Spatiality Scores n=18 Mean	SD
First	20.40	3.50	16.40	1.97	16.20	3.42	17.67	3.61
Second	17.53	3.48	18.27	2.20	17.27	1.87	17.69	2.64
Pooled Across Trials	18.97	2.65	17.33	1.66	16.73	2.42		

TABLE 10

Means and Standard Deviations:
Number of Moves in Practice Condition

Block of Trials	Spatiality Scores: High n=6 Mean	SD	Medium n=6 Mean	SD	Low n=6 Mean	SD	Pooled Across Spatiality Scores [illegible]8 Mean	SD
First	16.60	2.37	16.93	2.57	15.67	2.45	1[illegible].40	2.51
Second	19.13	1.93	17.67	4.55	15.47	2.27	17.42	3.48
Pooled Across Trials	17.87	1.82	17.30	3.36	15.57	2.32		

TABLE 11

Means and Standard Deviations:
Number of Moves in Control Condition

Block of Trials	Spatiality Scores						Pooled Across Spatiality Scores	
	High n=6		Medium n=6		Low n=6		n=18	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
First	15.87	1.15	18.47	2.43	14.67	1.85	16.33	2.46
Second	16.00	2.96	19.60	2.13	17.20	3.80	17.60	3.39
Pooled Across Trials	15.93	1.61	19.03	1.79	15.93	2.44		